

# Activity 5

## The Changing Geography of Your Community

### Goals

In this activity you will:

- Use several present-day distributions of minerals, rock formations, and fossils to help figure out the distribution of continents.
- Construct a map showing the position of continents 250 million years ago by reversing the present direction of plate motion.
- Recognize a convergence of presently widely scattered minerals, rock formations, and fossils when all the continents were part of Pangea.
- Compare present average community motions with that of the past 250 million years, by calculating the average yearly rate of motion over the last 250 million years.
- Describe the context in which the hypothesis of continental drift was proposed and why it was subjected to criticism.
- Show that your community has moved through different ecological regions over time.



### Think about It

The plates forming the Earth crust can be compared to pieces of newspaper torn from the same page.

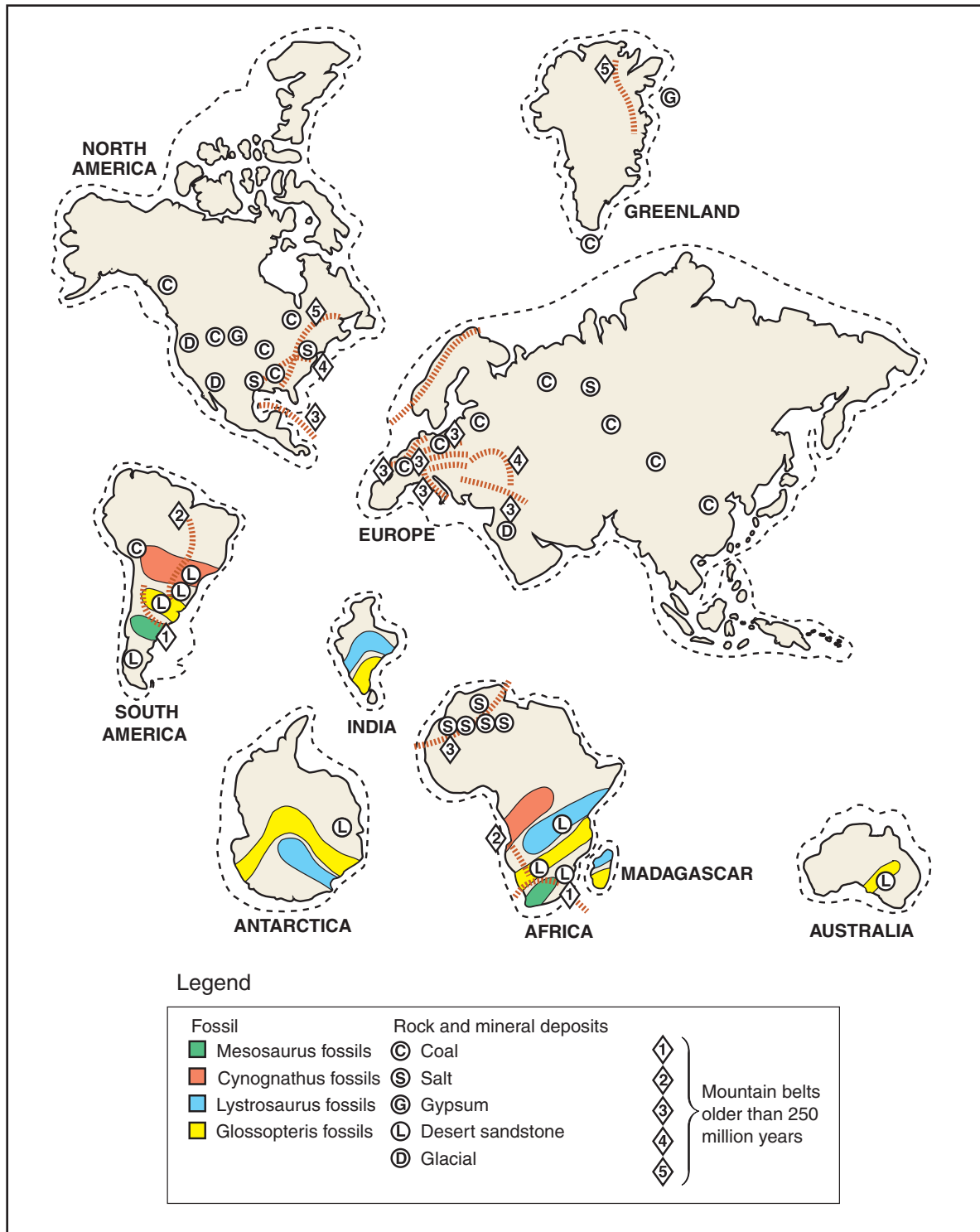
- How would you be able to decide if the pieces all came from the same page?
- How could you convince someone else that the pieces came from the same page?

What do you think? Record your ideas about these questions in your *EarthComm* notebook. Include sketches as necessary. Be prepared to discuss your responses with your small group and the class.



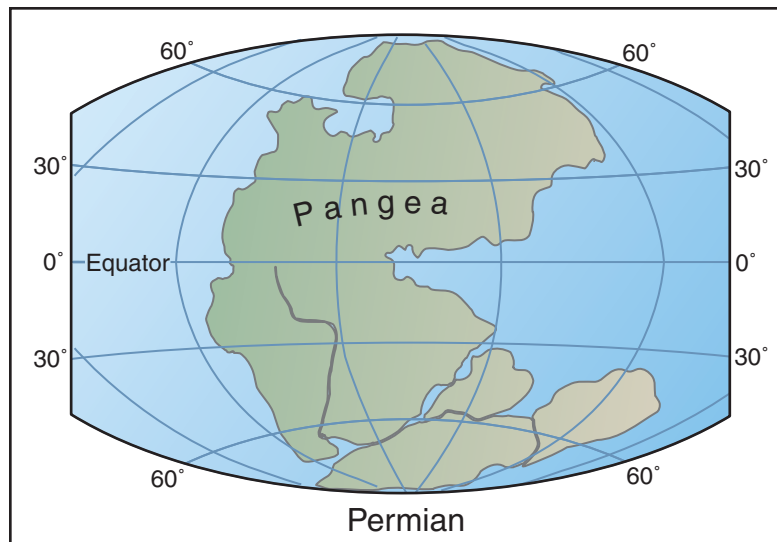
## Investigate

1. Begin your work individually. Obtain four copies of the diagram, showing the outline of the continents at sea level, as well as the boundary between the continental crust and the oceanic crust. The diagram also shows the location of rock formations, mountain ranges, and fossil plants and animals. Cut out the continents on the first sheet along the edges of the continental shelves, which in most places are close to the boundaries between the oceanic lithosphere and the continental lithosphere.
  - a) Why cut the pieces at the boundaries between the continental and oceanic crust?
  - b) In which ecological region is your community today: tropics, subtropics, mid-latitudes, subpolar, or polar?
  - c) Coal deposits originated in the swamps of tropical forests. Are the coal deposits shown on the map in the tropics today?
  - d) Where do you find mountains similar in structure to the Appalachian Mountains?
  - e) Where do you find rock formations similar to those in South America?
  - f) *Glossopteris* is an extinct seed fern that had leaves like ferns of today. It produced seeds too large to travel by air or float on water. Where are fossils of these ferns located today?
  - g) *Mesosaurus* is an extinct freshwater reptile that thrived during the Triassic Period (245 to 208 million years ago). Where are fossils of this reptile found today?
2. Rearrange the cut pieces on a blank piece of paper as the continents now appear and tape them in place.
  - a) Label the outlines "Present."
  - b) Draw a border around the map.
  - c) Sketch in and label the Equator and latitude lines at 30° and 60° north and south.
  - d) Title the map "Present."





3. Cut out the continents from the second sheet. Try to arrange them on another piece of paper, as they would have appeared 250 million years ago, before the Atlantic Ocean and the Indian Ocean began to open. You can do this by using two methods: (a) moving each continent in the direction opposite of that shown by the arrows on the map of plate motions on page G63; (b) matching similar rock formations, mountain ranges, and fossils from continent to continent. Try to move each of the continents at the speeds given by the lengths of the arrows, until they all meet. Tape the continents together.
- a) Draw a border around the map.
  - b) Sketch in and label the Equator and latitude lines at  $30^\circ$  and  $60^\circ$  north and south.
  - c) Title this map, “250 million years ago.”
  - d) The following diagram shows the reconstruction of Pangea that is generally accepted by geoscientists. Your reconstruction is likely to be somewhat different, because the evidence you had is less detailed. Compare your map with the following map, and adjust the positions of the continents on your map as required.



Generally accepted reconstruction of Pangea, in the Permian period of geologic time, 225 million years ago.

4. Use your adjusted map, “250 million years ago” to answer the following questions:
  - a) Which two continents fit together best?
  - b) Why do you think the continents do not fit together exactly?
  - c) From the map of Pangea, what can you say about the latitude and longitude of your community 250 million years ago?
  - d) In what ecological region was your community 250 million years ago?
  - e) Many coal deposits were created before 280 million years ago in the tropics. Where were they 250 million years ago? Does this make sense? Explain your answer.
  - f) Do the Appalachian Mountains line up with other mountain ranges that they resemble?
  - g) Do rock formations in South America line up with other formations that they resemble?
  - h) How does *Glossopteris* appear to have migrated to its present fossil distribution, since its seeds could not be carried by the wind or float on water?
  - i) How does *Mesosaurus* appear to have migrated to its present fossil locations, since it could not swim in the salty ocean?
5. Cut out the continents from the third sheet, in the same way as before. Arrange them on a new piece of paper, as they might appear 250 million years in the future. You can do so by starting with the present distribution of the continents and then moving each in the direction and at the speed shown by the arrows on the map of plate motions. Remember that some plates will be subducted under others.
  - a) What will fill the spaces between the continents in the future?
  - b) What will happen to the Mediterranean Sea? What will be created in southern Europe?
  - c) Where will the southern coast of California be in 250 million years?
  - d) In what latitude and in which ecological region might your community lie in 250 million years?
  - e) How might the change in ecological region affect your community?
  - f) Why might your prediction regarding the future location of your community and continent be in error?





## Reflecting on the Activity and the Challenge

You have seen that by moving the continents “in reverse,” in directions opposite to their present movement, you can make the continents fit together fairly well as a single continent. You have also seen that features like rock formations, mountain ranges, and fossil plants and animals that are similar but are

now separated by wide oceans are brought together when the continents are assembled into the single large continent of Pangea. You have gotten some idea about how far a particular place on a continent might have moved in the 250 million years since Pangea broke apart.

### Digging Deeper

#### DEVELOPMENT OF THE PLATE TECTONICS THEORY

In this activity, you examined some of the evidence that supports the idea that the continents of the Earth have moved during geologic time. Two features of the Earth were the subject of intense study in the late 1800s—the discovery of similar fossils on continents that are now separated widely by oceans, and the origin of mountain ranges. Both played a part in the early stages of the development of theory of plate tectonics.

In the late 1800s, an Austrian geologist named Eduard Suess (1831–1914) tried to solve a basic geological question: how do mountain ranges form? He based his model of mountain formation on some of the same principles that you explored in this chapter. Suess stated that as the Earth cooled from a molten state, the more dense materials contracted and sank toward the center, and the least dense materials “floated” and cooled to form the crust. He then speculated that mountain ranges formed from the contraction and cooling of the Earth. He likened this to the way that an apple wrinkles and folds as it dries out and shrinks.

Suess went on to explain the origins of oceans, continents, and the similarities of fossils on different continents now separated by oceans. In his model, during the cooling process, parts of the Earth sank deeper than others, forming the ocean basins. Suess claimed that certain parts of the sea floor and continents could rise and sink as they adjusted to changes in the cooling earth. This led him to propose land bridges between continents. Suess coined the term Gondwanaland for a former continent made up of central and southern Africa, Madagascar, and peninsular India. These areas all

contained similar fossils that were hundreds of millions of years old. According to Suess, the land bridges allowed various animals and plants to migrate and spread without crossing an ocean.

Although other geologists proposed different models to explain mountains, oceans, and fossils, all generally agreed that the Earth's crust moved up and down, but not very far sideways. Land bridges were often cited as allowing various kinds of organisms to move between continents now separated by oceans. According to Suess and others, the land bridges sank into the ocean long ago and no longer exist.

Not all geologists accepted the theory of a contracting Earth. In 1912, the German geoscientist Alfred Wegener (1880–1930) proposed the hypothesis of continental drift. He saw a variety of problems with the contraction theory. One difficulty was the severe compression of the Alps. The Alps are a young mountain range. Rock layers in the Alps are severely folded and stacked up on top of one another, indicating a great horizontal shortening of original distances, as shown in *Figure 1*. Wegener thought that contraction could not produce such great shortening of the Earth's crust. He also thought that contraction should produce uniform “wrinkles” in the Earth, not narrow zones of folding. The discovery of radioactive heat in Wegener's time also provided evidence against cooling. Heat from radioactive decay in the Earth would work against the cooling and contraction process.



**Figure 1** Wegener used the severe compression of the Alps as evidence to support his hypothesis of continental drift.





### Geo Words

**Pangea:** Earth's most recent supercontinent which was rifted apart about 200 million years ago.

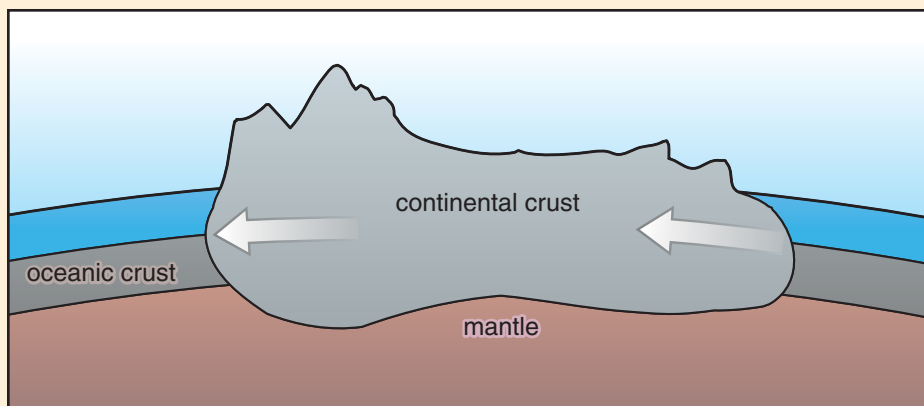
According to Wegener, about 200 millions years ago, a huge supercontinent called **Pangea** (Greek for *all land*) broke into separate continents that moved apart. Wegener claimed that compression at the leading edge of the moving continent led to the formation of mountains. Wegener's hypothesis allowed him to explain the different ages of the different mountain belts. He claimed that the timing of the breakup was variable, with some parts of Pangea separating earlier than others. His evidence included the puzzle-like fit of the continents and the similarity of rocks, geologic structures, and fossils on opposite sides of the Atlantic Ocean. Wegener's hypothesis eliminated the need for (now sunken) land bridges that once connected widely separated continents.

But how did continents move? Wegener thought that the material beneath the Earth's lithosphere acts like a slow-moving fluid. If this is true for vertical movements, it should also be true for horizontal movements. To visualize Wegener's argument, think about a piece of candy taffy or "silly putty." At the right temperature, taffy that will shatter when struck with a hammer will deform by flowing rather than by breaking when a force is applied slowly and constantly. Although other geologists saw folded mountains as evidence of contraction, Wegener saw folded mountains as evidence of horizontal compression caused by movement of the continents. The presence of folded mountains convinced Wegener that forces within the Earth are powerful enough to move continents. A quote from Wegener summarizes his ideas about the way that all the geological evidence "fit together":

"It is just as if we were to refit the torn pieces of a newspaper by matching their edges and then check whether the lines of print run smoothly across. If they do, there is nothing left to conclude but that the pieces were in fact joined this way. If only one line was available to the test, we would still have found a high probability for the accuracy of fit, but if we have  $n$  number of lines, this probability is raised to the  $n$ th power."

The reaction to Wegener's hypothesis was mixed. Some scientists accepted his arguments. Others argued that it would be impossible for continents to "plow through" the ocean floor (see *Figure 2*). Most geoscientists rejected Wegener's hypothesis. At an international meeting in 1926 devoted to the discussion of continental drift, only a handful of scientists were sympathetic to Wegener's ideas. One scientist raised 18 different arguments against Wegener's evidence! Although his evidence for drift was strong, the mechanism he proposed for the drift of the continents was inadequate.





**Figure 2** Wegener's proposal that continents plowed through oceanic crust was not accepted by many other geologists.

Convincing evidence began to emerge after World War II, as the sea floor was explored and mapped extensively. By the late 1960s, the theory of plate tectonics had been developed based on many types of evidence. Today, this evidence is considered so abundant and convincing that almost all geoscientists accept the theory. Much of the evidence that Wegener used to support his hypothesis supports plate tectonics. However, new evidence has emerged that provides a more plausible mechanism for the movement of the Earth's lithosphere.

Using evidence such as magnetic striping on the ocean floor (described in Activity 1), ages of ocean-floor basalts, outlines of continental plates, and the locations of similar fossils and rock types on widely spaced continents, geologists have reconstructed the record of the breakup of the supercontinent Pangea. Pangea started to break up about 200 million years ago, as continental rifts (divergent zones) began to open and oceanic crust began to form. As Pangea continued to be rifted apart, oceanic crust formed between the northern continents (called Laurasia) and the southern continents (called Gondwana). New ocean floor also was formed between Antarctica and Australia and between Africa and South America. India started to separate from Antarctica and travel northward.

The maps shown in *Figure 3* summarize what has been reconstructed as the breakup of Pangea, from 225 million years ago to the present. As you can see, continents that are now connected were not always that way, and continents that are now widely separated once were part of the same land mass.



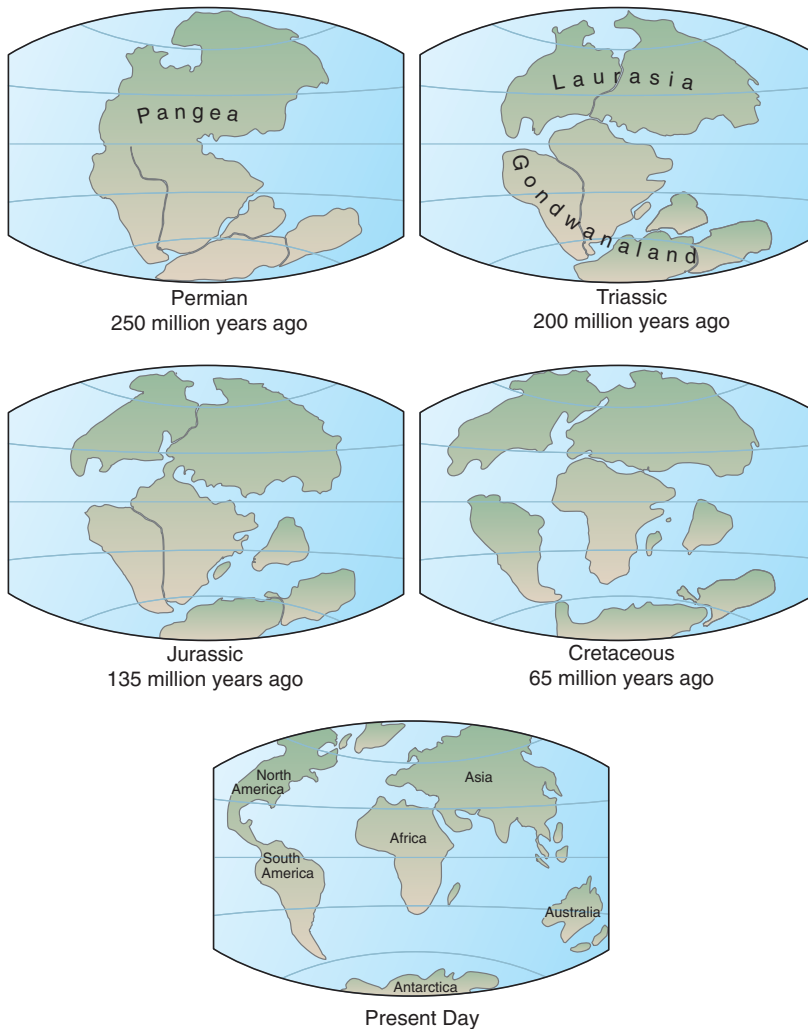


### Geo Words

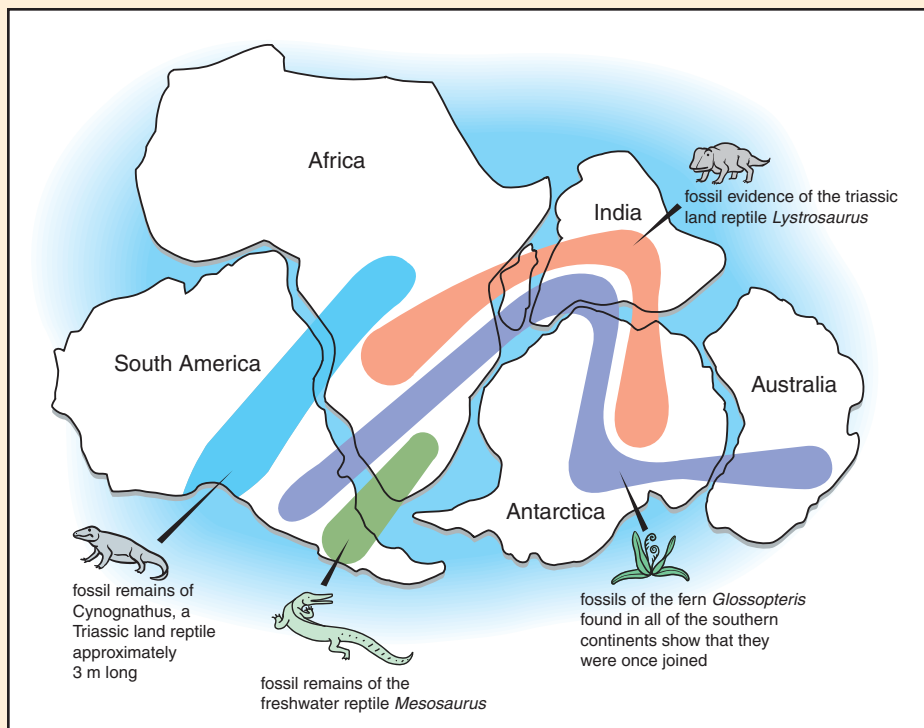
**supercontinent:** a large continent consisting of all of the Earth's continental lithosphere. Supercontinents are assembled by plate-tectonic processes of subduction and continent-continent collision.

Of course, 225 million years is a small fraction of the Earth's 4.5 billion year history. There may be rocks in your community much older than 225 million years. The positions of the continents prior to 225 million years ago can be reconstructed using the same types of evidence used for reconstructing Pangea, shown in Figure 4. The task is much more difficult, however, since the oldest oceanic crust geologists have ever found is only 200 million years old. Thus, the evidence for the earlier geography of the Earth must be gathered from the continents. Old mountain belts such as

the Appalachians of North America and the Urals (which separate Europe from Asia) help locate ancient collision zones between continents of the past. Rock types and fossils provide evidence for the locations of ancient seas, glaciers, mountains and ecological regions. Continents like Pangea, which consist of all of the Earth's continental lithosphere in one single piece, are called **supercontinents**. Geoscientists are fairly sure that there was at least one earlier supercontinent before Pangea, and maybe others as well. The cycle of assembly, breakup, and reassembly of supercontinents is called the Wilson Cycle.



**Figure 3** The breakup of Pangea.



**Figure 4** Evidence used to reconstruct Pangea.

### Paleomagnetism

You learned in Activity 1 that the mineral magnetite “locks” the Earth’s magnetic field into its atomic structure as it cools. Geoscientists collect rock samples containing magnetite and measure the past magnetism the rocks record (called **paleomagnetism**). They do this by putting the sample in a special room that is arranged so that the present Earth’s magnetic field is canceled out. The Earth’s magnetic field has the same pattern that would be observed if there were a giant bar magnet inside the Earth, lying along the Earth’s axis of rotation. There isn’t really a big magnet in the Earth; the magnetic field is thought to exist because of movements of liquid iron in the Earth’s core. *Figure 5* shows how the lines of the Earth’s magnetic field are arranged. The angle that the magnetic field lines make with the Earth’s surface changes from the Equator to the poles. Near the Equator the lines are nearly horizontal, and near the poles they are nearly vertical. This means that the paleomagnetism of a rock sample can tell you the latitude of the sample when it formed, called the paleolatitude. Measurement of

### Geo Words

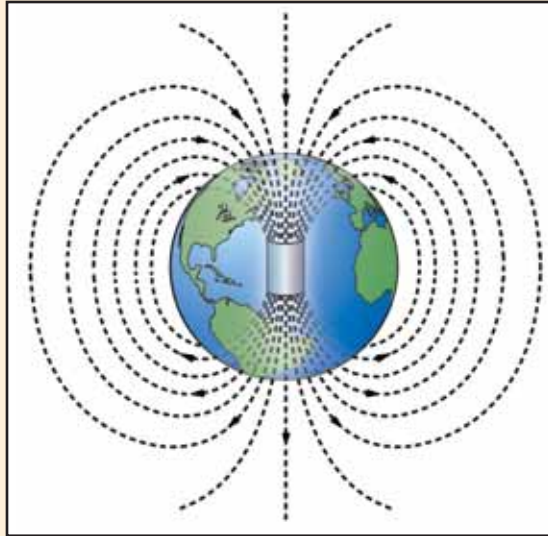
**paleomagnetism:** the record of the past orientation and polarity of the Earth’s magnetic field recorded in rocks containing the mineral magnetite.



### Check Your Understanding

1. How did Suess explain the formation of mountain ranges?
2. What evidence was found to contradict Suess's proposal that the Earth is cooling and shrinking?
3. What evidence did Wegener use to support his theory of the breakup of Pangea?
4. How did Wegener propose that the continents move horizontally?
5. How was fossil evidence used to reconstruct Pangea?

paleolatitudes is one of the things geoscientists use to reconstruct past supercontinents like Pangea. The big problem is that there is no way of measuring paleolongitude, because the magnetic field lines are always oriented about north–south! That's why no longitude lines are shown on the map of Pangea in the investigation.



**Figure 5** The diagram shows how the lines of Earth's magnetic field are arranged.

### Understanding and Applying What You Have Learned

1. Geoscientists often try to figure out paleogeography (the geography of land and sea in the geologic past) using the clues given on your continent puzzle pieces. What additional evidence would you need to be more confident about your “225 Million Years Ago” map?
2. Paleoclimatology is also used to show how continents were connected in the past. What type of climate data might have been helpful to you in making your “225 Million Years Ago” map?
3. Why was the theory of continental drift questioned when it was first proposed by Alfred Wegener?
4. What discoveries helped scientists begin to accept the idea that parts of the Earth's lithosphere move? Why were the more modern clues not available in Wegener's time?

5. New scientific theories often take many years to be accepted by the scientific community. Explain why this is so, using the theory of plate tectonics as an example.
6. The theory of plate tectonics is now accepted by almost all geoscientists. The theory overcomes the objections many scientists had to the idea of continents moving around the globe. How does plate tectonics explain the seeming movement of continents through rigid oceanic crust?
7. Describe what has happened to the lithosphere under the Atlantic Ocean during the last 200 million years. What has happened to the lithosphere under the Pacific Ocean? How does this information support the theory of plate tectonics?

## Preparing for the Chapter Challenge

In your notebook, write a brief essay describing how the arrangement of continents and oceans in the geologic past can be figured out, and what are the limitations to doing this.

Try to devise a way of animating the movements of all of the continents

from the time of the breakup of Pangea to the present time, so that the middle school students can watch the movements with their own eyes. Write up your ideas in your notebook. Compare your ideas with those of others in the class.

## Inquiring Further

### 1. History of science

The history of the development of the theory of plate tectonics is a fascinating one. A very important piece of evidence that supported plate tectonic theory was the discovery of paleomagnetism in ocean bottom basalts. How was this paleomagnetic evidence of sea-floor spreading discovered?

Write down in your notebook at least one additional question you have about the geologic history of your community. How would you go about gathering information to answer these questions? Write your ideas in your notebook.

### 2. Plate tectonics and the Earth system

Write an essay explaining how Earth systems would change if plate tectonics were to “stop.” You might begin with something directly connected to plate tectonics, such as volcanism or mountain building. For example, *“If plate tectonics were to cease, then global volcanism...”*